CHAPTER 1

THE IMPACTS OF URBAN RUNOFF

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INTRODUCTION

Urbanization can significantly impact surface waters by several mechanisms:

- As an area becomes urbanized, natural, pervious areas are typically covered with pavement, buildings and less pervious landscaped areas. This reduces the amount of rainfall infiltration to the groundwater and increases the amount of stormwater runoff. In addition, drainage improvements constructed during urbanization decrease the travel time of stormwater runoff. The result is that the peak stormwater discharge from the urbanized area is increased, and the low stream flow normally associated with shallow groundwater flow is decreased. Therefore the result of urbanization is higher stream flows during periods of rainfall and lower stream flows during dry periods.

- A second impact which is related to the changes in hydrology discussed above is streambank erosion caused by an increase in peak runoff. In order for a stream channel to accommodate the increase in peak flow it must erode a larger channel. The material from this enlargement becomes part of the bed load of the stream, taking many years to work its way downstream. This eroded material causes the same problems as sediments from other sources.

- A third major impact of urbanization is the long term impacts on water quality as a result of urban runoff. Urban development causes an increase in the pollutants in stormwater. These pollutants can vary widely from event to event and over the course of the year. These pollutants are a normal byproduct of modern urban life and include such pollutants as road salt, fertilizers, pesticides, heavy metals, oils, nutrients, oxygen-demanding substances, and bacteria.

WATER QUALITY IMPACTS OF URBAN RUNOFF

There are several mechanisms for depositing pollutants on the urban landscape. These include dryfall and wetfall of atmospheric pollutants; direct application of such materials as road salt and sand, fertilizers and pesticides; and applications which are unintentional but a normal result of urban activity, such as oil drippings from motor vehicles.

Pollutants are also picked up from the various surfaces in the urban environment. Trace metals are picked up from metal roofing and flashing, metal culverts, paints, and automobile products. As these materials age and corrode, some of the metals are released to the environment (Schueler, 1987).

Additional sources of pollutants include pet droppings, vegetative matter, litter and anything else deposited upon the urban landscape and capable of being washed off. These pollutants are picked up by runoff and carried along until the runoff reaches a water body.

The Rhode Island Department of Environmental Management, (1993) lists the following pollutant concentrations in urban runoff:

POLLUTANT (mg/l)	RESIDENTIAL[a]	COMMERCIAL[a]	INDUSTRIAL[a]	URBAN HIGHWAY[b]	RURAL HIGHWAY[b]	UNDEVELOPED
Total Phosphorus	0.620	0.290	0.420	0.491	0.209	0.061
Total Nitrogen	2.030	2.300	2.530	3.180	1.737	1.355
Copper	0.056	0.050	0.032	0.066	0.029	--
Lead	0.293	0.203	0.115	0.491	0.105	0.020
Zinc	0.254	0.418	1.063	0.404	0.105	0.081
TSS	228.0	169.0	108.0	174.2	53.5	--
BOD	13.0	14.0	10.0	--	--	--
COD	102.0	84.0	62.0	139.8	64.0	--

[a] Source: Whalen and Cullum, 1989
[b] Source USDOT, 1990 (urban highway >30,000 vehicles/day and rural highway < 30,000 vehicles/day)
[c] Source: Oakland et al., 1983 (copper data is suspect and atypical. therefore not reported)

A study in Maine documented the elevated levels of phosphorus export from developed watersheds. In adjacent watersheds, one developed and one undisturbed, phosphorus export from the developed watershed was up to ten times greater than from the forested watershed (Maine Department of Environmental Protection. 1989) This corresponds quite well with the Rhode Island Department of Environmental Management information.

Schueler, (1987) developed an empirical method. known as the Simple Method, for estimating pollutant export from urban development sites The table below is similar to one published by the Metropolitan Washington Council of Governments. but is based upon the National Urban Runoff Program (NURP) national average data.

Annual Storm Pollutant Export (Pounds/Acre) for Selected Values of Impervious Cover (I) Developed from the Simple Method[1,2] are as follows:

LAND[3] USE	SITE IMPERVIOUSNESS %	TOTAL PHOSPHORUS	TOTAL NITROGEN	BOD 5-DAY	ZINC[4]	LEAD[4]
RURAL RESIDENTIAL	0	0.19	1.35	4.86	0.07	0.07
	5	0.36	2.57	9.22	0.14	0.14
	10	0.53	3.78	13.59	0.20	0.21
LARGE LOT SINGLE FAMILY	10	0.53	3.78	13.59	0.20	0.21
	15	0.69	5.00	17.96	0.27	0.27
	20	0.86	6.21	22.33	0.33	0.34
MEDIUM DENSITY SINGLE FAMILY	20	0.86	6.21	22.33	0.33	0.34
	25	1.03	7.43	26.70	0.39	0.40
	30	1.20	8.64	31.07	0.46	0.47
	35	1.37	9.86	35.44	0.52	0.54
TOWNHOUSE	35	1.37	9.86	35.44	0.52	0.54
	40	1.54	11.07	39.81	0.59	0.60
	45	1.71	12.29	44.18	0.65	0.67
	50	1.88	13.50	48.55	0.72	0.73
GARDEN APARTMENT	50	1.88	13.50	48.55	0.72	0.73
	55	2.05	14.72	52.92	0.78	0.80
	60	2.21	15.94	57.29	0.85	0.87
HIGH RISE LIGHT COMMERCIAL/ INDUSTRIAL	60	2.21	15.94	57.29	0.85	0.87
	65	2.38	17.15	61.66	0.91	0.93
	70	2.55	18.37	66.03	0.98	1.00
	75	2.72	19.58	70.40	1.04	1.06
	80	2.89	20.80	74.77	1.11	1.13
HEAVY COMMERCIAL, SHOPPING CENTER	80	2.89	20.80	74.77	1.11	1.13
	85	3.06	22.01	79.14	1.17	1.20
	90	3.23	23.23	83.51	1.24	1.26
	95	3.40	24.44	87.88	1.30	1.33
	100	3.57	25.66	92.25	1.36	1.40

[1] P(rainfall depth)=40 inches, Pj(runoff correction factor for storms that produce no runoff)=0.9, Rv(runoff coefficient)=0.05+0.009(I), I=% site imperviousness, C(mean concentration of pollutant)=NURP National Average Values, A(area)=1 acre.

[2] These values are based on NURP national average values and may not be applicable to all situations

[3] Rural Residential: 0.25-0.50 Dwelling Units (DU)/acre
Large Lot Single Family: 1.0-1.5 DU/acre
Medium Density Single Family: 2-10 DU/acre
Townhouse and Garden Apartment: 10-20 DU/acre

[4] Extractable

IMPACTS OF SPECIFIC POLLUTANTS

Sediment. Suspended sediments constitute the largest mass of pollutant loadings to surface waters (United States Environmental Protection Agency, 1993). Sediment causes an increase in turbidity and a decrease in light penetration and resultant impairment of photosynthesis of aquatic plants. It can smother benthic life; impair the respiration of fish and aquatic invertebrates. Sediment deposits in shallow areas of lakes and ponds can provide a suitable substrate for aquatic plant colonization. Sediment can carry significant quantities of nutrients; and can significantly decrease recreational values (United States Environmental Protection Agency, 1993; Schueler, 1987; New York Department of Environmental Conservation, 1992).

The primary source of sediment in urban runoff is construction related. However, sediment also results from increased streambank erosion; winter sanding of roadways; erosion of high traffic areas of unpaved urban surfaces, and natural soil erosion.

Nutrients. Nutrients (particularly phosphorus) can have a dramatic impact upon freshwater lakes and ponds. Phosphorus is the limiting nutrient for most lakes and ponds and an increase in phosphorus can cause a corresponding increase in algae. Algae are microscopic plants which are common in our lakes, with the addition of excess phosphorus their populations can increase rapidly. In a worse case, the algae populations may soar causing an algae bloom, discolor the lake water, and cause odors as the algae die and decay. Algae growth can also lead to the lowering of a lake's oxygen supply, and the elimination of certain species of fish. High nitrogen loadings can lead to similar problems in coastal areas.

Urbanization changes the natural landscape, which normally would retain most of the nutrients falling on it. Land disturbance upsets the environment's ability to retain phosphorus. Stormwater flowing over the land surface picks up phosphorus and transports it either in soluble form or attached to soil particles. The phosphorus is from numerous sources both natural and human and includes eroded soil, road dust, plants, fertilizers and detergents (Maine Department of Environmental Protection, 1989).

Nitrogen, like phosphorus, is very common in the natural environment. There are many sources of nitrogen including animal waste and decaying plants and animals. The urban landscape being largely impervious, the opportunity for the removal of nitrogen from stormwater is limited.

Oxygen-Demanding Substances. Organic matter which falls on, and accumulates on the landscape is washed off during runoff events. This organic matter utilizes oxygen in its decomposition. This oxygen utilization places an oxygen demand on the receiving water body. BOD levels in urban runoff can exceed 10 to 20 mg/l during storm "pulses" which can lead to anoxic conditions (zero oxygen) in shallow, slow-moving or poorly-flushed receiving waters (Schueler, 1987). The NURP study found that oxygen-demanding substances can be present in urban runoff at concentrations similar to secondary wastewater treatment discharges (United States Environmental Protection Agency, 1993).

The greatest export of BOD occurs from older, highly impervious residential areas with outdated combined storm sewers and large populations of pets. In contrast, only moderate BOD export has been reported from newer, low density suburban residential development (Schueler, 1987).

Trace Metals. Trace or heavy metals are typically found in urban runoff. These metals are important due to their potentially toxic effects upon aquatic life and the potential to bioaccumulate in fish and shellfish (United States Environmental Protection Agency, 1993). The most prevalent metals in urban runoff are copper, lead and zinc (United States Environmental Protection Agency, 1993; Schueler, 1987).

A large portion of trace metals are attached to sediment. This means that they are not immediately available for biological uptake and the metals associated with sediments, are easily removed by sedimentation (Schueler, 1987).

Other Pollutants of Concern. Urban runoff will contain bacteria levels which frequently exceed public health standards (Schueler, 1987); oils and grease from motor vehicles and other similar sources; toxic chemicals from a variety of sources; and road salt used in deicing. Lastly, urban runoff can be a source of thermal pollution. Rainfall falling on roofs and pavement which have been heated by the sun will be heated by these surfaces. The elevated temperature of this runoff can be stressful or even lethal to certain aquatic organisms (Schueler, 1987; New York Department of Environmental Conservation, 1992).

The United States Environmental Protection Agency (1993) presents the following general table of sources of urban runoff pollutants:

Source	Pollutants of Concern
Erosion	Sediment and attached soil nutrients, organic matter, and other adsorbed pollutants
Atmospheric deposition	Hydrocarbons emitted from automobiles, dust, aromatic hydrocarbons, metals, and other chemicals released from industrial and commercial activities
Construction materials	Metals from flashing and shingles, gutters and downspouts, galvanized pipes and metal plating, paint, and wood

Sources of Urban Runoff Pollutants (Continued)

Source	Pollutants of Concern
Manufactured products	Heavy metals, halogenated aliphatics, phthalate esters, polynuclear aromatic hydrocarbons, and pesticides and phenols from automobile use, pesticide use, industrial use, and other uses
Plants and animals	Plant debris and animal excrement
Non-stormwater connections	Inadvertent or deliberate discharges of sanitary sewage and industrial wastewater to storm drainage systems
Onsite disposal systems	Nutrients and pathogens from failing or improperly sited systems

As neighborhoods age their urban runoff tends to have significantly higher pollutant concentrations. Older neighborhoods tend to become less pervious over time with additional building activity, driveways, decks, patios, and the general compaction of the pervious areas. As trees mature in these areas the underlying grassed areas tend to die off, leaving bare earth. The pollen and leaf fall from these trees, which would be retained on a forest floor in a natural area, is now washed off with the runoff (Schueler, 1987)

SUMMARY

Rainfall and runoff are natural occurrences in our environment. The urbanization of the landscape however, can have significant impacts upon runoff. This chapter together with Chapter 2 discuss the impacts upon the environment by urbanization. The remaining chapters will discuss the various measures available to mitigate these impacts. These measures are numerous and the needs of the development and its watershed will often dictate which measures to use.

As a general rule, the less the concentration of runoff, and the less sophisticated the treatment measure, the better the solution. Natural solutions are preferred over constructed solutions, i.e., buffer strips are preferred to water quality inlets. However, it is recognized that certain developments in highly urbanized areas do not have sufficient land area for natural treatment methods.

Proper planning of the development is important as it has been shown that the directly connected impervious areas are the most critical to the quantity, rate and pollutant concentration of the runoff. Proper planning can allow for landscaping which incorporates areas for shallow ponding, and infiltration, overland flow through vegetated areas, and minimizes directly connected impervious areas. In areas requiring stormwater detention for peak flow reduction it is frequently best to combine the treatment and detention measure in one device such as an extended detention pond, wet pond, or created wetland.

Because some amount of infiltration is inherent in most stormwater treatment options the following criteria should be followed regarding siting:

- Runoff from residential and commercial properties should be diverted and treated outside the protective radius of community ("C") and non-community, non-transient ("P") public water supply wells (i.e., 200 feet from small, less than 57,600 gallons per day and 400 feet from large 57,600 gallons per day or more C and P wells).

- Runoff from industrial or petroleum storage and /or dispensing sites should be diverted and treated with a non-direct infiltration option 500 feet from a small and 1000 feet from a large C or P well (Pillsbury, 1995).

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